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Lean beyond company borders: costs or benefits?

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Lean beyond company borders: Costs or benefits?

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Purpose - This paper brings lean principles outside the walls of the factory and applies them to the overall supply chain with respect to transportation in particular. We present a solution that increases trailer density by transporting components hanging on rails instead of piling them up.

Design/method/approach - A calculation model, validated by a case study, illustrates the different cost drivers across the supply chain and reveals the savings and investment expenditures of the new concept.

Findings - The results from a case study show that smoothening the flow of products between the different supply chain partners and increasing the trailer density by 25% results in a reduction of 20% in transportation costs. Based on three critical product characteristics, multiple products are researched in a 2^3 design to gain insights in the market analysis and the practical use.

Practical implications - Looking for innovative ways to transport goods can lead to transportation cost savings, new business models and a smoother flow of products.

Originality/value - The model contributes to the literature by increasing the transparency about the drivers that influence the costs of the different players in the supply chain. Moreover, the paper shows the financial impact of innovations in transporting and handling components.

Key words - Supply chain logistics, lean transportation, returnable packaging, assembly industry, case study

Paper type - Case study

1. Introduction

Nowadays, many production and assembly operations are optimized in order to minimize waste and maximize value. Lean thinking is widely spread in the internal logistics of a manufacturing plant, but is hardly found in the external logistics. For instance, goods are wrapped in plastics, put in containers and loaded with forklifts into a trailer in order to reverse these steps at the destination.

In many supply chains, transportation remains a key aspect in physically linking the supply chain partners. Rogers and Weber (2011) acknowledge the importance of transportation as an integrated function and argue that it should become more sustainable and more productive. However, the average load factor of the laden trips of European trucks is about 55% according to the European Environment Agency (EEA) (2010). Furthermore, about one in every three trucks is running empty (EEA, 2010). Not surprisingly, increasing the utilization of trailers is mentioned as one of the top three means to reduce costs in a survey (Kayser *et al.*, 2008). The rising oil prices, additional emission legislation and an escalating demand have put the commercial vehicle business under great competitive pressure.

These forms of waste are surprising in a sector that focuses on cutting costs. Therefore, a reconsideration of traditional packaging, the introduction of a new container design so as to reduce non-value-adding space utilization and smoother in- and outbound operations may have a major influence on the cost drivers of intra supply chain transportation.

This study is performed in cooperation with conTeyor, a Belgian manufacturer of reusable textile packaging solutions. In order to tackle the discrepancy between external and internal logistics, the Total Supply Chain Concept (TSCC) has been developed in order to let products flow directly from the production line at the sender's side into the trailer on a universal carrier, to deliver them at the assembler's side in the right sequence. As a result, packaging waste is minimized. In this vein, the paper introduces an innovative supply chain concept into the sustainable logistics literature. ConTeyor's solution is used to develop a cost model that allows comparing a traditional transportation with an environment with lean, minimum packaging and that can consequently capture the benefits that are still to be realized within the transportation sector. Moreover, the model contributes to the literature by increasing the transparency about the drivers that influence the costs of the different players in the supply chain, further referred to as cost drivers.

This paper looks at the impact of this innovative way of transportation between the different stages of the supply chain and how and where overall improvements are attained. The research question that is tackled is to investigate whether lean transportation is possible and what concepts could be introduced to rethink the transportation. The impact of the different settings on the traditional cost components and the influence of the main cost drivers are examined. Secondly, a cost/benefit analysis of eight types of products serves as a case study to gain insights into the market potential of the lean transportation concept.

The remainder of this paper starts with a literature overview that positions the different aspects of the business case into an academic context. Subsequently, the lean transportation concept as developed by conTeyor is outlined and serves as a practical solution towards the lean management of the external logistics. The identification of the cost drivers and the case study approach that is utilized for the quantification of the cost drivers is found in the next sections. Next, the model inputs and test products are discussed. The monetary impact and instigation towards generalizability conclude this paper.

2. Literature

Lean principles have been studied widely in the literature, mainly in internal manufacturing operations and to a more limited extent in supply chains and logistics. Liker (1997) emphasizes that lean thinking focuses on reducing non-value-adding processes. Womack and Jones (2003) argue that it is a way to do more with fewer resources in order to provide the customer with exactly what he wants. Besides, they claim that the lean principles, despite the fact that they usually appear in a manufacturing context, can be applied in any company of any industry. However, research on lean transportation in particular is very limited.

From the list of waste types that have been identified by Ohno (1988), this paper deals with transportation and packaging waste. As transportation adds time and space utility, it could also be used as a strategic differentiator (Martichenko and Taylor, 2006). Packaging is often only seen as a cost component although it can add value to all logistical activities if properly designed (Chan *et al.*, 2006). In the past years, returnable packaging has proven to have economic and environmental advantages compared to its disposable counterpart (González-Torre *et al*., 2004; Silva *et al*., 2013). A functional packaging design enables flexibility and increased packaging density for instance. Additionally, returnable packaging offers a longer lifetime, increased protection and a decrease in the amount of required material and waste. In return, a reverse logistics system, involving all supply chain partners, must be set up and managed properly (Kroon and Vrijens, 1995; Chan, 2007).

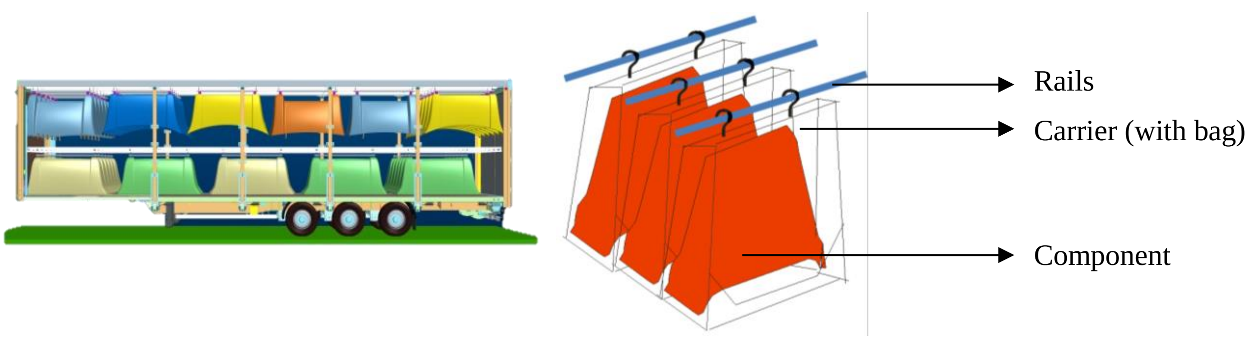
This paper contributes to the literature in its expansion of lean thinking outside of the company's boundaries towards the transportation sector and by involving the sender (manufacturer), the receiver (assembler) and the carrier into the analysis. Moreover, it case study-wise quantifies the cost drivers of the innovation in external logistics with real data, something that is often lacking in the current academic literature.

3. The lean transportation concept

The total supply chain concept (TSCC) supports the one-piece flow design rule that is said to be triggered by the customer's demand (Black, 2007). In traditional batch production, every part in the batch waits for the completion of the other parts. Before moving to the next station, the products need to be put into boxes and containers and will be unloaded and unpacked at the receiver's side. The TSCC wants to reduce these non-value-adding activities.

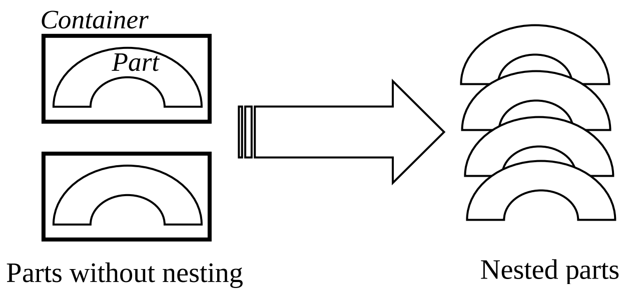
In the TSCC, components are stored in a reusable textile bag in order to protect them against movement and scratches and travel one by one hanging on carriers. This carrier is a foldable construction that allows the products to hang on rails inside the trailer like shirts on a clothes hanger as shown in Figure 1. Since the truck needs to wait until the trailer is filled, the nature of transportation does not allow one-piece flow in the strictest sense. The goal of the TSCC is that the goods can flow as smoothly as possible, without bottlenecks or waste. A piece or component comes from the production line and is placed on the carrier. It does not leave the carrier until it is ready to be used in the final assembly. Consequently, extra materials for transport such as cardboard boxes, pallets or containers are eliminated and the trailer itself is now considered as the handling unit. The removal of excess packaging (e.g., steel racks) results in a higher trailer density thanks to the possibility of nesting the parts as shown in Figure 2.

Figure 1: Elements of the TSCC: Hanging parts in the trailer (a), illustration of carriers on rails (b)



(a) (b)

Figure 2: Increasing density by nesting the components



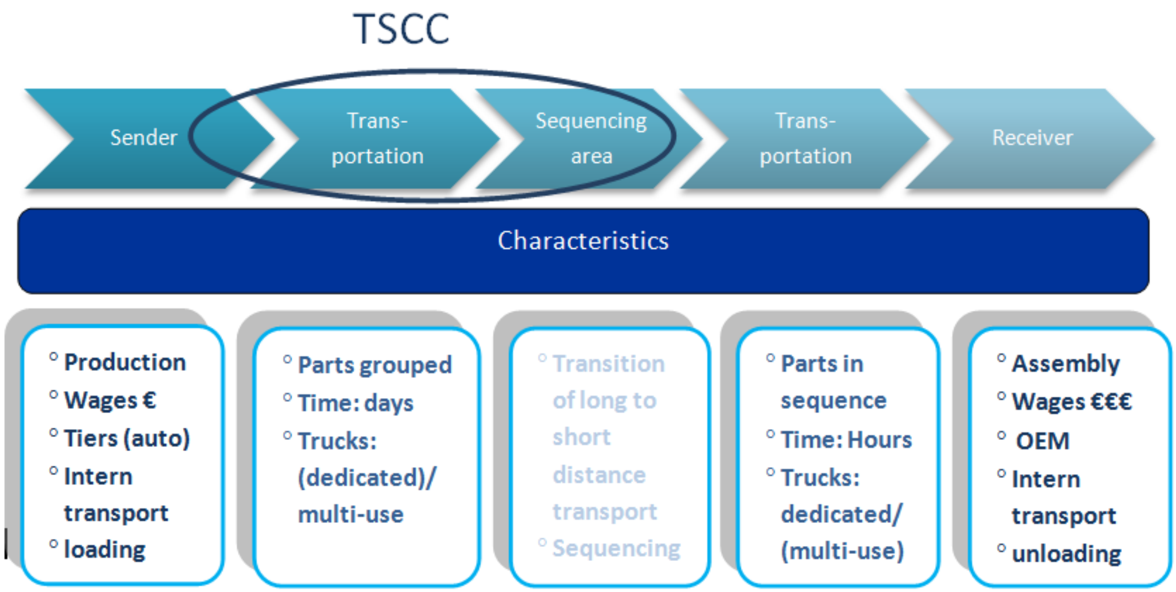
The schematic example demonstrates that if parts in a container are now hung up on a carrier, the unused space in the containers can be used for nesting other parts. The carriers themselves are not shown in the figure.

The TSCC is built on the concept of returnable packaging. Moving from an environment where goods are packed in boxes or wrapped in plastics to the adoption of returnable packaging requires a considerable change in cost management. Packaging is no longer an annual operating expense, but changes into a single capital expenditure and is bought to be used for several years. Logistical carriers or returnable transport items can be any type of box, container, pallet or trolley and play a pivotal role in logistical handling. They not only hold the product together, but they also serve activities related to storage, loading transportation and information transfer (e.g., Prendergast and Pitt, 1996).

In the TSCC, goods are no longer piled up but hang down on carriers. Hanging transport (potentially combined with RFID tags) is already in use in internal logistics where it increases the process efficiency. In external logistics, it is only found in the fashion and the meat industry, where returnable packaging is mostly used for short distances. Hanging transportation requires an adapted trailer design in order to support a flexible internal rail system. An investment in a specialized trailer, in a docking system to connect the external to the internal logistics and in the carriers replaces the annual operational cost for disposable packaging and aims to smoothen the flow of products throughout the supply chain.

We assume the TSCC in a business-to-business environment. In particular, the TSCC is mainly positioned inbetween the production and the assembly of goods and requires the cooperation of the suppliers, the assembler, the carrier and a truck manufacturer. The distance between the suppliers and the (sub-assembler of the) original equipment manufacturer (OEM) is large because the former is often located in low-cost countries due to fierce competition on this level, while the latter is located closer to the market. The packaging loop consists of components, returnable packaging and waste. On the contrary, the distance from the sequence centre or sub-assembler to the OEM is typically only a few kilometres. The packaging loop here sometimes consists of dedicated one-piece flow transport. It is assumed that the TSCC is implemented in the first transportation loop, shown in Figure 3, because it is estimated that this area of the supply chain offers the largest potential for cost savings in terms of density gain.

Figure 3: Overview of the supply chain and the positioning of the TSCC



4. Methodology

The investigation of the benefits and costs of the supply chain and transportation reconfiguration relies on a case study approach. In order to model the lean supply chain, the project builds on the concept as it is implemented by conTeyor. This company provides all the relevant technical details and the cost assumptions of the investments. The cost drivers are identified through interviews with the different entities of the supply chain: a returnable packaging producer, a trailer manufacturer, a machine constructor and different suppliers in the automobile sector. Together with the information that the academic literature offers, a list of cost drivers is constructed. A consultation of industry experts and industry reports together with data from the academic literature assist the quantification of the model's parameters.

After the validation by the industry panel, we have defined three significant cost drivers: the volume of the product, the shape of the product and the demand of the product. Determining two levels for each dimension, a 2^3 matrix has been constructed and for these eight elements an example product has been chosen in order to execute the cost/benefit analysis. For each case, an investment and NPV analysis indicate whether this product is suitable for the TSCC. For the case of door panels, a more detailed analysis is presented.

Of course, it is essential to bear the rigidity of this case study approach in mind (Yin, 2014). The cost framework is very case-specific, so one needs to beware for the generalization of the case study findings. Local economic factors, product characteristics and the features of the supply chain have an influence on the outcome of the analysis. Nevertheless, this study serves as guidance in the analysis of whether this innovative reconfiguration could bring solace in different industries.

5. The cost drivers

In several supply chains, the costs related to loading, unloading, packaging and other indirect costs are allocated to production or overhead fees which makes transparency of the specific cost drivers difficult

(Liang and Ma, 2010). While this transparency is crucial, a survey by Huber and Sweeney (2007) reveals that 59% of the 776 respondents did not know their total supply chain cost. At the same time, logistic cost management is nowadays an important way to gain a competitive advantage. Liang and Ma (2010), for instance, provide the cost drivers for a material conveying system. Pettersson and Segerstedt (2013) discern six cost categories in the supply chain, including manufacturing, administration, warehousing, capital, installation and distribution cost. They also examine how and to what extent supply chain costs are measured in different companies. In this paper, we want to identify and quantify these cost drivers that are significantly influenced by the lean transportation idea of the TSCC. Basically, five cost driver categories have been distinguished for the overall supply chain: packaging, transportation, internal handling, loop size and the initial investments.

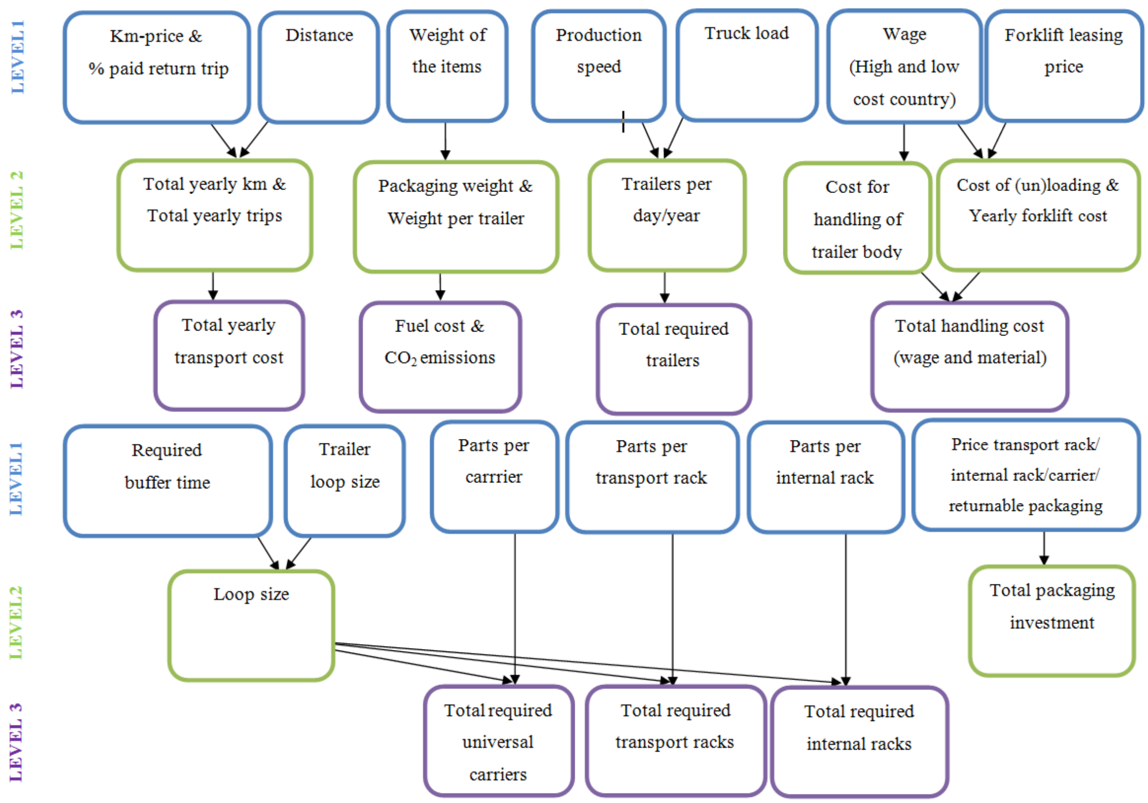
In order to assess the potential of lean transportation, a cash flow analysis of the cost drivers is of paramount importance. In general, the model examines one-to-one relationships between production and assembly. However, often other parties come into play resulting in an m-to-n relationship with m receivers and n senders or suppliers. Table 1 lists the main cost drivers and Figure 4 represents how the underlying parameters are interrelated.

Table 1: Cost drivers and the corresponding TSCC impact

Cost driver	Impact of the TSCC
Quantitative	
Amount of packaging material	Textile bags allow for flexibility and less waste No over-dimensioning of packaging
Type of packaging material	Moving from disposable packaging towards returnable packaging
Truck density	Possibility of nesting of (irregularly shaped) products
Truck weight	Weight reduction due to light carriers and textile bags instead of steel racks and supplementary packaging Higher truck load density leads to a weight increase
Number of trips	Increased trailer density leads to lower number of trips
Return loop	Foldable racks and less returnable packaging material allow for transport of other loads
Kilometer-price	Efficient use of the trailer density and the return journey cuts transportation costs
Personnel cost	The reduction in handling time and the removal of forklifts result in a decrease of the personnel cost
Handling time	Increase in set-up time for container installation Faster loading and unloading and reduction in sequencing time decrease handling time
Internal handling units	Carriers partly replace internal handling units (e.g., racks, trolleys)
Forklift	Forklift-free environment leads to more flexibility in packaging, decreased stack pressure and fewer damages
Loop size	Inventory and buffer depend on the inventory management of the company
Qualitative	
Ergonomics	Increased safety due to smaller weights, absence of forklifts and pushing

	of products instead of carrying
Quality	Automation leads to fewer mistakes
	Less damage during transportation and handling
Supplier relationship	Longer-term relationships with suppliers instead of short-term transportation rate driven relationships
Sustainability	Increase in sustainability of the relations in the supply chain (e.g., less fuel consumption, better ergonomics, no packaging waste)

Figure 4: Overview of the relationships between the input cost drivers (level 1) and other relevant values



5.1. Packaging

Packaging drastically changes if the TSCC is implemented. A traditional environment involves not only returnable packaging units, racks and dollies, but also disposable materials like boxes, pallets and plastics. Jönson *et al*. (2000) attribute about 5 to 10% of the total logistical cost to packaging. Moreover, the disposal of packaging waste must be considered. Besides, the lifespan of pallets is dependent on their type and quality and on the transportation characteristics, but Hekkert *et al.* (2000) assume that returnable wooden pallets are used, on average, for 20 trips while plastic ones are used for 50 trips. On the contrary, no disposable packaging is involved in the TSCC, while returnable packaging consists of the textile bags and the carriers of the hanging components. The lifespan of these returnable items is typically five to seven years. In the model, this is incorporated as an annual maintenance cost that is expressed as a percentage of the initial cost. Another possibility is to include the probability of the necessity of cleaning, repair and replacement.

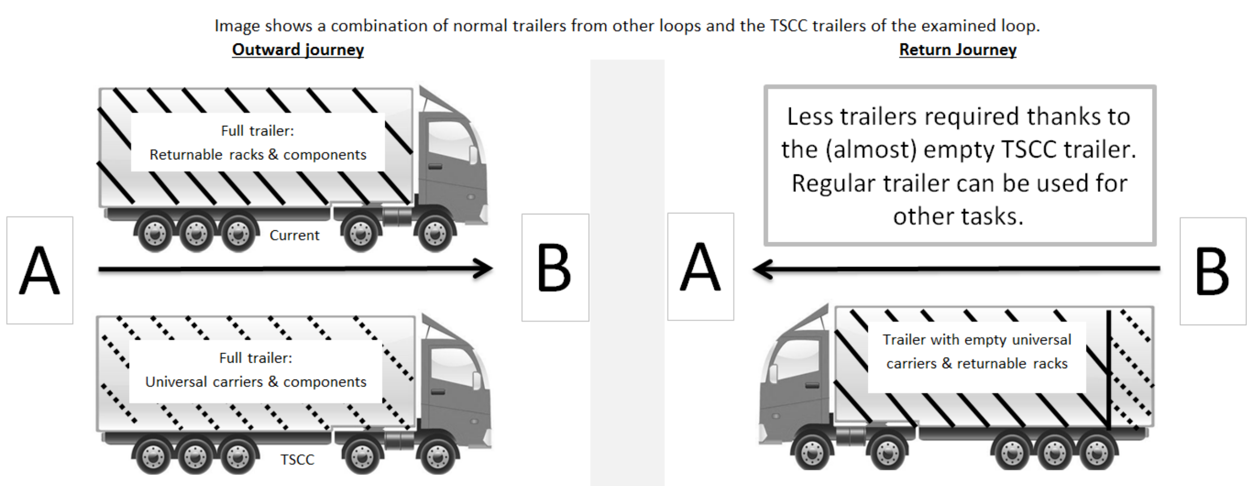
5.2. Transportation

Many shippers pursue a trailer density increase. This could be realized by adapting the product design to lower the occupied space. Although the TSCC has no impact on the design of the product itself, it increases the density by lowering the amount of packaging and by nesting the products. The flexibility of the product-specific textile packaging avoids over-dimensioning of the packaging which is usually the case in an environment with cardboard boxes or steel racks. Nesting results in a decrease of the unused air space between two loaded components. Nevertheless, the gains strongly depend on the shape and the dimensions of the component and the weight limitations of the trailer.

The TSCC offers opportunities for additional return transport optimizations. Return transport and reverse logistics aim to minimize waste and disposal at the end of the supply chain. Therefore, return transport requires the cooperation of several companies, but it is often poorly managed because each firm is mainly looking at its own optimization process (Chan, 2007). In a traditional setting with returnable packaging, trucks leave fully loaded with components and returnable packaging that may occupy a lot of space on the return trip. Using returnable universal carriers that are foldable and additionally take little space and are light, offers the advantage of having a trailer that is almost empty (only containing the carriers) for the return trip. This can result in returning only a fraction of the trailers or returning all of them, but combining return freights of other loops (e.g., to another supplier as shown in Figure 5). Similar to the milk run concept, the trailer may for instance store empty racks from other returnable packaging loops and trucks may pass by other suppliers to drop off racks before returning to the starting point. The case studies assume that each trailer returns with only the empty, foldable carriers to serve as a base case showing minimal savings. Later, the additional benefits of horizontal collaboration or returning only a fraction of the trucks are shown.

In summary, the savings in trailer space allow for a higher trailer loading factor and efficiency optimizing reconfigurations of the return trip. Of course, this is highly flow-dependent and if it is impossible to find freight for the return trip, the trailer will be used for very expensive one-way transport without realizing return benefits. Nonetheless, the reduction in the total number of trips will also benefit the aims to reduce CO_2 emissions that are related to the fuel consumption.

Figure 5: Savings in return transport in the TSCC scenario

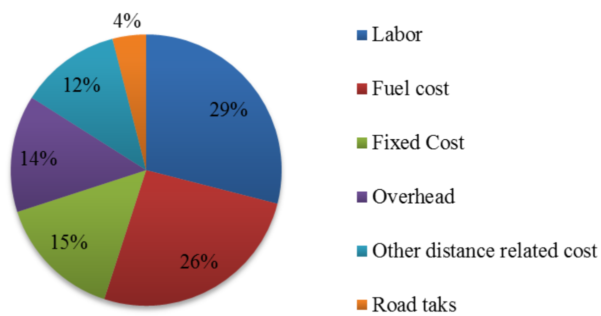


The charged kilometer price plays a pivotal role in the cost/benefit analysis of the transportation cost. As shown in

Figure **6**, based on two reports (Kayser *et al.*, 2008; KPMG, 2011), this price is mainly determined by the country-specific labor costs and the fuel cost, next to fixed costs (i.e., depreciation, interest, insurance) and other distance related costs (i.e., maintenance and repair, tires). The size of each cost part strongly depends on the regulations in the country, but labor and fuel cost are overall the two biggest cost elements. Common prices are € 1.22 per kilometer (France) and € 1.30 per kilometer (Germany) (Macchi and Raballand, 2009). These are costs for a full trailer load. Apart from a fixed price per km that is applied in our model, Janic (2007) proposes a distance-dependent transportation cost. Moreover, return trips are usually less costly than one-way trips, which is taken into account in the model.

Depending on which party invests in the trailer, two options are distinguished. Firstly, the model assumes that the OEM invests in the trailer and cooperates with a carrier to manage the fleet. Therefore, the price per kilometer is adjusted for the fraction that reflects the trailer investment. A conservative 10% reduction of the kilometer price is proposed to represent the depreciation costs (KPMG, 2011). Secondly, the third party carrier might invest in the trailer, which would result in a leasing setting and which requires a modification of the allocation of costs in the analysis.

Figure 6: Composition of the transportation cost



5.3. Internal handling

Time is identified to be an important aspect in lean environments because it is reflected in the financial terms by using wages of forklift drivers, warehouse personnel and truck drivers. The TSCC and the inherent automated flow reduce the handling time significantly since the components can roll out of the trailer instead of being handled per rack (manually or by forklift).

In most large production environments, the forklift is a crucial element for handling and storage operations. Its flexibility allows it to be used in the entire logistical flow. Companies used to buy forklifts, but recently firms more and more opt for five to seven years leasing contracts (Bond, 2012), which is reflected in the model. However, forklifts have major disadvantages like safety risks (Larsson and Rechnitzer, 1994) and the impact forces that regularly cause damages (Gilbert and Rasmussen, 2011). Consequently, companies in the automotive sector are looking for a way to eliminate or reduce the use of forklifts, so that the TSCC could bring solace.

5.4. Loop size

An important factor in returnable logistics is the loop size, which reflects the number of packaging units that are needed to ensure sufficient units throughout the supply chain. It includes both the units in buffer as well as the number of units required to cover the transportation time. It is expressed as $P * t/v$, with P the daily production rate, v the number of parts per returnable packaging handling unit and t the total loop time in days as the sum of the transportation time and the required buffer time at both the sender as well as the receiver. Albeit outside of the scope of this paper, the required buffer size depends on the inventory policy of the company, but is usually calculated using the safety stock, the line or shop feeding inventory, the delivery frequency, the storage of empty racks and the shipping preparation buffer. It is important to monitor all the parameters that determine the buffer size and the transit time since a significant change in these parameters can influence the number of required returnable packaging units and could cause shortages.

5.5. Investments

TSCC requires extra investments. The new trailer might be the largest investment next to an adapted docking system. In the model, the financial leasing option of the trailers is considered. The annual leasing cost is calculated as an annuity for the purchase price over a period of 60 months with an effective interest rate of 2.5% and a conservative assumption of zero expected residual value. The cost of leasing debt, which is considered here as 2.5% for a five-year lease, is used as a discount factor. Furthermore, the model assumes that it is an all or nothing story: either all necessary trailers are acquired or the project does not go through. The comparison runs as follows: when opting for the TSCC option, new TSCC trailers are purchased and the old ones are potentially sold, while remaining at the current option assumes using the currently available fleet. It is assumed that the current fleet can cover the demand. If this would not be the case, extra regular trailers should be arranged for which increases the costs for the current scenario.

Except for the trailer, all investments are assumed to be fully paid for at the start of the project. It is project-specific who pays for packaging. In a first setting, the sender pays for the investment and decides which type of packaging to use within certain requirements of the OEM or assembler. The sender then also owns the packaging. Secondly, sometimes the OEM pays and loans the packaging to the supplier with guidelines on how to deliver the products. Alternatively, a third party pooler owns the package and rents the containers to the sender (Kroon and Vrijens, 1995). Last but not least, the supplier pays the initial investment, but the amount is gradually reimbursed by the OEM per delivered component. In the results of this paper, both packaging and transportation are paid for by the sender, but this does not make a difference for the overall results. For the case study, it is assumed that reusable packaging is already used in the form of steel racks.

6. Products

Based on the literature on lean and agile, the question rises in which industries these concepts could be applied. In general, lean implementations work best in sectors where products are commodities and have a long life cycle, where demand is predictable, margins are low and cost is the central focus (Christopher and Towill, 2000, Purvis *et al.*, 2014). However, this does not entirely answer the question yet. Which product characteristics are in particular most suitable for introducing the TSCC? To get insights into this question, one product for each of the two levels of three product dimensions is examined, as shown in Table 2. The categorization should be interpreted relative to other products. The products are chosen to match the categorization criteria and according to data availability.

Table 2: Categorization of the products

		Shape			
		Irregular/sensitive (fragile)		*Regular*	
		Size		Size	
		Large	*Small*	*Large*	*Small*
Demand	*High*	Dashboard	Car doors	Fridge door	TV-screen
	Low	Plane engine	Forklift seat	Generator	Oil filter

Three product characteristics are the basis for the 2^3 design based on product shape, demand volume and product size (volume). For the latter, the surface-to-volume ratio decreases when the edges of the components get bigger. This demonstrates that the smaller the parts, the more packaging is necessary relative to the used volume. As a result, components that are very small are less cost-efficient and thus not considered. When scanning an assembler's product range, one can see that, given a certain production volume and a minimum desired delivery frequency (e.g., one trailer per day), the minimum required volume of the component can be calculated and can guide the product selection for a TSCC project within a company. Furthermore, since components are now hanging, the force it takes to move a product is less than for piled components, which allows more weight for the same ergonomic restrictions.

In order to examine the potential of different product characteristics, several cost drivers are assumed to remain constant for the comparison. Appendix A lists the data. The following cost drivers will determine the production and supply chain characteristics: the truck load in the TSCC and in the current situation, the weight per component, the volume of the component, the production speed and the number of parts per handling unit in both the current as well as the TSCC scenario. Appendix B summarizes the details for all eight products.

7. Results and discussion

Firstly, a detailed analysis is conducted and reported for the transportation of door panels between a tier-one supplier and the OEM. Subsequently, the findings for the seven other products are discussed.

7.1. Car door panels

The main purpose of the innovation is to increase the trailer utilization in order to minimize transportation waste. The results show that the density of the trailer increases by 25%. Moreover, the percentage of used trailer volume improves from 56% to 70%, disregarding the volume of packaging.

With respect to the savings, the largest gain comes from savings in transportation costs, responsible for 89% of the savings, followed by the savings resulting from the forklift removal. Due to the high importance of the transportation cost into the total cost picture, higher distances lead to larger savings. In the automotive sector, for instance, the TSCC will be the most beneficial if it is installed between the tiers and the sequence centers of the OEM.

Regarding the investments, the packaging units (i.e., the universal carrier in the TSCC scenario and the current returnable packaging, of which the transport rack is the biggest cost, in the current scenario) capture the largest part of the investments in both scenarios. The investment in universal carriers and internal racks is 23% more costly than the investments needed for the current returnable packaging. It must be noted that the universal carrier is a packaging concept that is not in line with the concept of economies of scale. This explains why the investment in universal carriers is significantly higher than the investment in the current returnable packaging. The trade-off between a one-piece flow and lowering the required investment by putting more parts on one universal carrier must be examined in each case.

The total annual operational savings of the case study are € 271,488. This is enough to cover the total annual trailer leasing cost. The total net investment over the whole supply chain sums up to € 277,000 for the first year. For the test case data, a payback period of 1.96 years results from the model and the net present value (NPV) is positive with an amount of € 397,439.

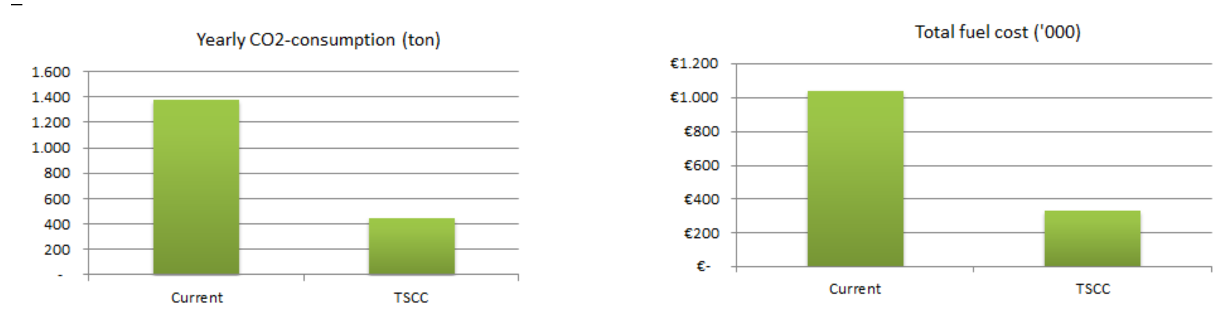
Since transportation and packaging are two influential factors, a more detailed analysis for these two elements is executed. For transportation, the difference in the annual travelled distance is 124,781 km. In order to cover the transportation loop between the supplier and the OEM, 2.5 trailers less are needed, leading to a decrease of about 125 trips on a yearly basis. For packaging, an increase of more than 6,720 units of logistical carriers can be observed, which in this case increases the packaging maintenance cost.

The handling cost decreases due to a faster way of (un)loading (i.e., the parts can roll out of the trailer and do not need to be handled separately), due to a lower number of trucks and the absence of the forklift. This results in savings of € 5,126.

Furthermore, the weight analysis depends on the direction of two factors. First of all, the weight is pushed down since the heavy transport racks are replaced by the lighter universal carriers. Secondly, the total weight might increase due to an increase in the number of products per trailer. In the case of the door panels, an overall weight decrease is observed. The weight of the packaging relative to the weight of the component has declined.

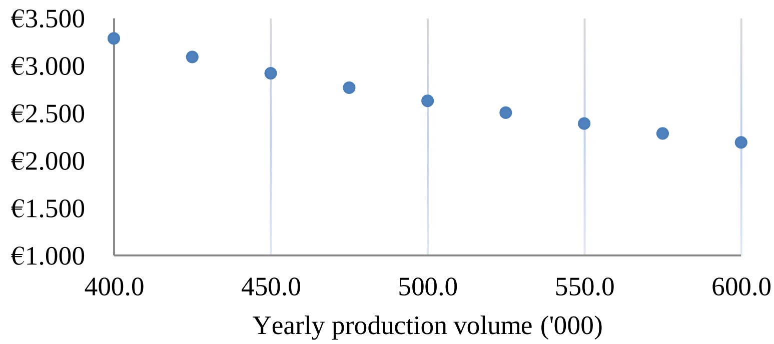
The transportation sector is responsible for about 22% of the global energy emissions and therefore more sustainable solutions in this sector are of utmost importance (Ortolani *et al*., 2011). The TSCC results in a decrease of about 937 tons CO_2 per year. On top of this, the fuel cost drops by € 703,048 which reflects more than 400,000 liters of fuel savings. Figure 7 shows the CO_2 analysis, excluding the savings of the freed up trailers in the transportation loops

Figure 7: CO_2 analysis for the yearly trips



Finally, Figure 8 shows the cost per transported product for different values of the yearly production volume in the TSCC scenario, including the leasing cost and the amortized investments. For the test case, this results in a cost per transported part of € 3.04. With regards to the cost per transported part, economies of scale can be realised.

Figure 8: Annual cost per transported part for different production volumes



7.2. Product range analysis

Table 3 reports the results for all analyzed products. Products with a regular shape are less likely to result in large savings, compared to products with an irregular shape or fragile products. The reason is that the opportunities for nesting are larger in the latter case. Moreover, the size of the product matters most when it is considered in combination with the demand volume. High demand enhances the effect of density increase per trailer and therefore this is a beneficial product characteristic for the TSCC. Sectors with high demand are for instance brown goods, white goods and electronics. For electronics, however, the product needs to be large enough in order to provide sufficient delivery frequency. Note that a continuous and high volume production would be ideal. Seasonal products will be less favorable because the use of returnable packaging is less useful in that case and therefore less likely.

Several remarks can be made for the analyzed products. First of all, for the plane engine, the increase in density is 25% thanks to the large nesting opportunities, but the component is that heavy so that the trailer's weight capacity and not the density becomes the limiting factor. Moreover, the combination of low demand and large volume results in a low ratio of required carriers to transport racks and an increasing importance of the savings in (un)loading. Secondly, the dashboard case shows that a highly irregular shape offers room for large improvements. Thirdly, for the fridge doors, the density increase is only 13%, which shows that this is a key factor driving the results. Nevertheless, the weight benefits are still significant. Fourthly, the delivery frequency (based on the demand speed and the volume of the component) needs to be taken into account. As such, the number of trucks leaving per day is lower than one every two days for the generator, the forklift seat and the oil filter. If the frequency is not a problem for the manufacturer, the forklift seat gives good results. The oil filter, however, has a low frequency in combination with a relatively low density increase, making it less attractive for the TSCC. It also suffers from weight limitations. Finally, in some cases (e.g., the generator) no density increase is realized. This can happen when a product has a regular form, easily stackable packaging that fits the product shape and beneficial product dimensions compared to the trailer dimensions.

Table 3: Results for the eight analyzed products

Product	Positive NPV?	Payback period (year)	Transportation cost	Density trailer
Dashboard	Yes	0	-28%	+39%
Car doors	Yes	1.96	-20%	+25%
Fridge door	No	-	-	-
TV-screen	Yes	4.08	-21%	+26%
Plane engine	No	Potential load increase exceeds weight limit trailer		
Forklift seat	Yes	1.94	-27%	+38%
Generator	No	-	-	-
Oil filter	Yes	3.39	-14%	+16%

7.3. Cooperation

The model's results allow for negotiations on how to divide the savings among the partners of the supply chain and on how the cost of packaging and transportation is charged to the other partners. As such, a new business model can be set up, in which the carrier invests in the new trailers and a gain sharing model is splitting the overall benefits. The carrier is then contracted for a lower number of trips due to the density increase, but can profit from the freed up space on the return trip. Moreover, this specialized transport might lead to new demand for the carrier or new price settings. This new business model would strengthen the relationships between the partners. Note that once the trailer is also used for transporting goods in the regular way, the time for deconstructing the rail structure should be included in the calculations.

7.4. Sensitivity

The model provides a sensitivity analysis to analyze the effect of changes in all cost drivers (ceteris paribus) on the NPV and the payback period. There are three groups of cost drivers that are highly sensitive and that one of the partners could influence: the truck load, the parts per returnable handling unit and carrier and the pricing of all TSCC elements. For instance, a 15% drop in the TSCC truck load makes the NPV for the car doors, TV-screens and oil filter turn negative. Increasing the number of parts per universal carrier to two (for the products having only one per carrier in the base case) makes the case of the fridge door financially attractive and increases the NPV of the already positive products by at least 14%. Moreover, as mentioned before, the base case assumes that the TSCC trucks all return without extra load. If we assume a more realistic scenario in which every third truck returns, the savings increase and the TV-screens case then has a payback period of 1.15 years and allows for a decrease of 45% in transportation costs.

Several changes in the basis assumptions may influence the result. For instance, when the TSCC trailers can be replacements for old trailers or if the carrier needs to renew his fleet, the results would highlight the TSCC savings. Moreover, the base model assumes zero product damages due to forklift movements, potentially underestimating the lost value. Additionally, fixed and regular loops are required in order to make the use of returnable packaging attractive. The longer the loop, the larger the business opportunity. When the comparison is with a supply chain that currently uses disposable packaging, the benefits of returnable packaging are additional to the ones discussed before. Nevertheless, in supply chains that already adopt foldable packaging, TSCC is less likely to be economically beneficial. Finally, when the internal system is based on hanging transportation, the connection with the trailer can lead to automatic unloading and a direct flow to internal handling. This would also enable to load the parts in the right sequence for the final assembly.

7.5. Future opportunities

The TSCC project is only the beginning of a shift in thinking about how to transport goods and to smoothen the connection between internal and external logistics. There are several aspects that deserve further attention. Future research could focus on the expansion of the TSCC downstream in the supply chain in order to include the customer. In addition, when viewing a trailer as a warehouse-on-wheels, a good connection between the trailer and an internal hanging transportation system must be examined, which includes a docking and an inventory system. The delineation of a buffer system that matches to the TSCC can unfold new opportunities or challenges. Research on optimal hanging transportation can give more insight into optimal truck loading. Moreover, the effects of the TSCC on the inventory should be examined. Furthermore, the current model focuses on transporting one specific product, extensions towards multiple similar or complementary products of the same company or other companies, as proposed in the horizontal collaboration literature, can be useful.

8. Conclusion

This paper investigates whether lean transportation is possible and what concepts could be introduced to rethink the transportation in the supply chain. Secondly, a case study for several products provides insights into the potential of this innovative transportation concept. The nature of the methodology prohibits generalizing the results to all supply chain settings, but the findings are still relevant to grasp the potential of the proposed concept.

The changed way of transporting goods leads to a significant drop in transportation costs, which is almost entirely achieved by the increase in truck load. Moreover, the model provides the necessary transparency in the cost drivers related to the transportation of goods between two supply chain partners. TSCC brings along several advantages inside the factory such as the elimination of the forklift trucks, less logistic personnel and a faster (un)loading process.

Overall, this research indicates that extending the lean principles to transportation could result in an opportunity for cost reduction coming from outside the walls of the factory. The truck load, the pricing of the TSCC elements and the number of parts per carrier both in the current as well as in the proposed scenario are very sensitive cost drivers and require sufficient attention in each project. In addition, the product analysis shows that TSCC is not appropriate for every industry because for instance a sufficient production volume is needed to grasp the benefit of lower transportation costs.

The transportation sector is a struggling industry with complex tensions. Improving the trailer utilization is one of the remedies to increase the profitability. The TSCC project shows that increases of more than 25% are possible which is a significant progress in the transportation industry. Besides, an increased density also benefits the society since it reduces the CO_2 emissions.

This paper suggests that the strive for reducing waste should not stop at the factory walls. Hence, the innovation train has not yet reached its destination and the challenge is to keep rethinking the current ways of transporting and packing goods in order to find sustainable solutions.

9. References

Black, J.T. (2007), “Design rules for implementing the Toyota Production System”, *International Journal of Production Research*, Vol. 45 No. 16, pp. 3639–3664.

Bond, J. (2012), “Lift truck financing: Understanding lifespan”, *Logistic Management*, Vol. 51 No. 7, pp. 50–54.

CEFIC (2011), “Guidelines for measuring and managing CO_2 emission from freight transport operations”, available at: www.cefic.org (accessed 8 April 2013).

CFM International (n.d), “CFM56-3 Turbofan Engine”, available from: http://www.cfmaeroengines.com/engines/cfm56-3 (accessed 8 December 2014).

Chan, F.T.S., Chan, H.K. and Choy, K. L. (2006), “A systematic approach to manufacturing packaging logistics”, *International Journal of Advanced Manufacturing Technology*, Vol. 29 No. 9-10, pp. 1088–1101.

Chan, H.K. (2007), “A pro-active and collaborative approach to reverse logistics - A case study”, *Production Planning & Control*, Vol. 18 No. 4, pp. 350–360.

Christopher, M. and Towill, D. R. (2000), “Supply chain migration from lean and functional to agile and customised”, *Supply Chain Management: An International Journal*, Vol. 5 No. 4, pp. 206–213.

Donati, P. and Patel, J.A. (1999), “Subjective assessment of fork-lift truck seats under laboratory conditions”, *Applied Ergonomics*, Vol. 30 No. 4, pp. 295-309.

European Environment Agency (2010), “Load factors for freight transport (TERM 030)”, available at: www.eea.europa.eu/data-and-maps (accessed 23 December 2014).

European Environment Agency (2011), “Specific CO_2 emissions per tonne-km and per mode of transport in Europe: 1995-2011”, available at: www.eea.europa.eu/data-and-maps (accessed 10 March 2013).

Gilbert, B.P. and Rasmussen, K.J.R. (2011), “Determination of accidental forklift truck impact forces on drive-in steel rack structures”, *Engineering Structures*, Vol. 33 No. 5, pp. 1403–1409.

González-Torre, P.L., Adenso-Díaz, B. and Artiba, H. (2004), “Environmental and reverse logistics policies in European bottling and packaging firms”, *International Journal of Production Economics*, Vol. 88 No. 1, pp. 95-104.

Hekkert, M.P., Joosten, L.A.J. and Worrell, E. (2000), “Reduction of CO_2 emissions by improved management of material and product use: The case of transport packaging”, *Resources, Conservation and Recycling*, Vol. 30 No. 1, pp. 1–27.

Huber, B., Sweeney, E. (2007), “The need for wider supply chain management adoption: Empirical results from Ireland”, *Supply Chain Management: An International Journal*, Vol. 12 No. 4, pp. 245-248.

Janic, M. (2007), “Modelling the full costs of an intermodal and road freight transport network”, *Transportation Research Part D: Transport and Enivronement*, Vol. 12 No.1, pp. 33–44.

Jönson, G. and Johnsson, M.. (2000). “Packaging logistics: Evaluation methods for increased efficiency in the supply chain”, in *Proceedings of the International Conference on Computer Integrated Manufacturing, 2000*, Singapore, pp. 185-197.

Kayser, H., Kuhnert, F. and Karlsson, B. (2008), “The truck industry’s green challenge: Headwind or competitive edge”, available at: www.pwc.be (accessed 8 February 2013).

KPMG (2011), “Competing in the global truck industry: Emerging markets spotlight”, available at: www.kpmg.com (accessed 10 March 2013).

Kroon, L. and Vrijens, G. (1995), “Returnable containers: An example of reverse logistics”, *International Journal of Physical Distribution & Logistics Management*, Vol. 25 No. 2, pp. 56–68.

Larsson, T.J. and Rechnitzer, G. (1994), “Forklift trucks - Analysis of severe and fatal occupational injuries, critical incidents and priorities for prevention”, *Safety Science*, Vol. 17 No. 4, pp. 275–289.

Liang, X. and Ma, J. (2010), “Application of PCA in controlling and reducing enterprise logistic cost”, *Second International Conference on Modeling, Simulation and Visualization Methods in Sanya*, IEEE, pp. 275-278.

Liker, J.K. (1997), *Becoming Lean: Inside Stories of U.S. Manufacturers*, Productivity Inc., Portland, OR.

Macchi, P. and Raballand, G. (2009), “Transport prices and costs: The need to revisit donors’ policies in transport in Africa”, Working Paper No. 190, Bureau for Research & Economic Analysis of Development, Duke University, Durham, NC, 22 November.

Martichenko, R. and Taylor, L. (2006), “Lean transportation: Fact or fiction?”, available at: http://images.fedex.com/us/autodistrib/LeanTransportationFinal101606.pdf (accessed 24 July 2013).

Ohno, T. (1988), *Toyota Production System: Beyond Large-scale Production*, Productivity Press, New York, NY.

Ortolani, C., Persona, A. and Sgarbossa, F. (2011), “External cost effects and freight modal choice: Research and application”, *International Journal of Logistics Research and Applications*, Vol. 14 No. 3, pp. 199-220.

Pettersson, A.I. and Segerstedt, A. (2013), “Measuring supply chain cost”, *International Journal of Production Economics*, Vol. 143 No. 2, pp. 357-363.

Prendergast, G. and Pitt, L. (1996), “Packaging, marketing, logistics and the environment: Are there trade-offs?”, *International Journal of Physical Distribution & Logistics Management*, Vol. 26 No. 6, pp. 60-72.

Purvis, L., Gosling, J. and Naim, M.M. (2014), “The development of a lean, agile and leagile supply network taxonomy based on differing types of flexibility”, *International Journal of Production Economics*, Vol. 151, pp. 100-111.

Rogers, M.M. and Weber, W.L. (2011), "Evaluating CO_2 emissions and fatalities tradeoffs in truck transport", *International Journal of Physical Distribution & Logistics Management*, Vol. 41 No. 8, pp. 750-767.

Siemens (n.d.), "Siemens OEM products – Generators", available at: https://w9.siemens.com/cms/oemproducts/Home/Products/Pages/Generators.aspx (accessed 8 December 2014).

Silva, D.A.L., Santos Renó, G.W., Sevegnani, G., Sevegnani, T.B. and Serra Truzzi, O.M. (2013), "Comparison of disposable and returnable packaging: A case study of reverse logistics in Brazil", *Journal of Cleaner Production*, Vol. 47, pp. 377-387.

Texas Transportation Institute (2012), "A modal comparison of domestic freight transportation effects on the general public", available at: www.nationalwaterwaysfoundation.org/study/FinalReportTTI.pdf (accessed 7 December 2013).

The Boeing Company (2013), "Orders and deliveries", available at: http://active.boeing.com/commercial/orders (accessed at 8 December 2014).

Womack, J.P. and Jones, D.T. (2003), *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Simon & Schuster, London.

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.),Thousand Oaks, CA: Sage Publications.

Appendix

A. Basis assumptions

Table A: Overview of the test case data

Cost driver	Value
Weight per universal carrier	2 kg
Weight per packaging bag	1 kg
Weight of the current packaging per rack	5 kg
Weight per transport rack	150 kg
Weight of rail structure in the trailer (TSCC)	2,000 kg
Percentage time saving in (un)loading in TSCC (per trailer)	30%
Percentage of (un)loading done by forklift	100%
Trailer loop time	5 days (roundtrip)
Trailer used for other purpose? (yes/no)	Yes
Single trip distance	1,000 km
Type of replacement of trailers (new/replacement)	New (extra)
Docking installation R. (manual/automatic)	Manual
Docking installation S. (manual/automatic)	Manual
Use of forklift Sender (yes/no)	Yes
Use of forklift Receiver (yes/no)	Yes
Maintenance racks and returnable packaging	5% of purchase price
Number of forklifts in use for loading S.	1 forklift
Number of forklifts in use for loading R.	1 forklift
Use of returnable packaging (yes/no)	Yes
Required buffer time Sender	1.8 day
Required buffer time Receiver	1.6 day
Daily holding cost per component S[a]. (365 days)	€ 0.02
Daily holding cost per component R. (365 days)	€ 0.02
Number of days the firm is running/working days	250/220 days
Percentage time forklift driver on (un)loading	100%
Use of foldable racks (yes/no)	No
Volume of the trailer (Megatrailer: 13.6x2.4x3.0 m)	97.92 mm^3
Who is paying for transportation?	Sender
Who is paying for packaging?	Sender
Disposable packaging costs	None. Use of returnable packaging
Recycling costs	None. Use of returnable packaging
Efficiency increase over the years	0%
Cost per universal carrier	€ 100
Cost per internal rack for universal carrier	€ 250
Current cost per internal RP unit (without racks)	€ 380
Cost per transport rack	€ 500
Amortisation period/Cost of capital (leasing)[b]	5 years/2.5%
Hourly wage regular worker high/low cost country[c]	€ 24.15/€ 8.05
Hourly wage truck driver	€ 16.83
Leasing price	€ 650/month
g CO_2/ton/km[d]	107/89/70-80
Litre fuel/1000 kg/100 km & fuel price per litre	4 l/€ 1.5
Time to (un)load a full trailer/ Time to (de)construct the rails	25 min/60 min
Old trailers are replaced?	No
Price per km/ % to be paid for return trip	€ 1.3 (one way)/80%
Current number of parts lost due to forklift damage	0

Maximal weight of the load	10 tons
Racks/dolly	1 rack
Price TSCC trailer	1.8 x regular megatrailer
Docking hardware and installation	€ 27,500

Note. S. = Sender. R. = Receiver. FL = Forklift. RP = Returnable packaging
[a] Calculation is based on the online prices of a logistics provider.
[b] According to the trailer manufacturer a period of five to seven years is standard. Cost of capital according to a Belgian Bank.
[c] Wage according to a Belgian public employment centre in 2013. Low cost country is assumed to be one third.
[d] Sources are respectively the Texas transportation institute (2012), CEFIC (2011), EEA (2011). The value of the last reference is chosen in the product cases.

B. Product specific assumption

The data for the car door panels, the TV-screens and the car dashboard are based on real business cases from conTeyor. For the other data, a combination of assumptions and data that are available online has been used. We assume that the parts are transported from a supplier to an assembler.

Table B: Overview of data for the market analysis

	Yearly production ***(units)***	**Density current** ***(units)***	**Density TSCC** ***(units)***	**Weight part** ***(kg)***	**Dimensions L x B x H** ***(mm)***	**Parts/ RP HU** ***(units)***[a]	**Carriers/ internal rack** ***(units)***
Car door (case)	500,000	790	984	3.5	1,000x580x 120	10	5
TV-screen (case)	1,500,000	495	624	7	1,160x783x 118	8	5
Dashboard (case)	450,000	144	200	20	570x681x 1,330	4	5
Generator[b]	330	260	192	150	1,020x570x 542	2	2
Fridge door[c]	1,000,000	2,250	2,550	15	70x870x540	5	5
Plane engine[d]	1,202	8	10	1,940	2,438x1,539x 1,539	1	1
Forklift seat[e]	18,750	256	352	15	400x470x500	8	6
Oil filter[f]	125,000	1,920	2,232	11	791x210x210	10	10

Note. RP = Returnable packaging, HU = Handling unit.
[a] Two parts per universal carrier for products with ten or more parts per RP HU. For other parts, one carrier per product.
[b,c] Current truck load is based on a box with 10 cm extra in each dimension compared to the product and the full trailer dimensions (13.6*2.4*3.0 m). The TSCC load is based on the product dimensions and the trailer dimensions, adapted for packaging, resulting in 85.5 m³ usable volume. Estimations for the generator dimensions and weight are based on a generator from Siemens (Siemens n.d.).
[d] For the current truck load, same assumptions as for (b,c) hold. The production speed for the models Boeing 737, 747,767,777,787 is 601 in 2012 (two engines per plane are assumed), measured in the number of deliveries (The Boeing Company 2013). The engine CFM56, build for the 737 is used for dimension calculations (CFM International n.d.). Due to nesting possibilities, a prudent estimation of two extra parts in the TSCC is assumed.
[e] Production speed: data from conTeyor. The assumed dimensions of the seats are in line with the sizes found in the literature (Donati & Patel 1999). The current transport is assumed to happen with heavy transport racks, where each seat is placed in a predefined spot. This assumption is backed up by the online packaging proposals of current logistics providers.
[f] Assumptions based on the datasheet of Atlas Copco. Assumptions of current transport are based on a box with a profile width of 5 cm and 10 cm extra in each dimension per part (5 cm at each side, analog to notes b,c).

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